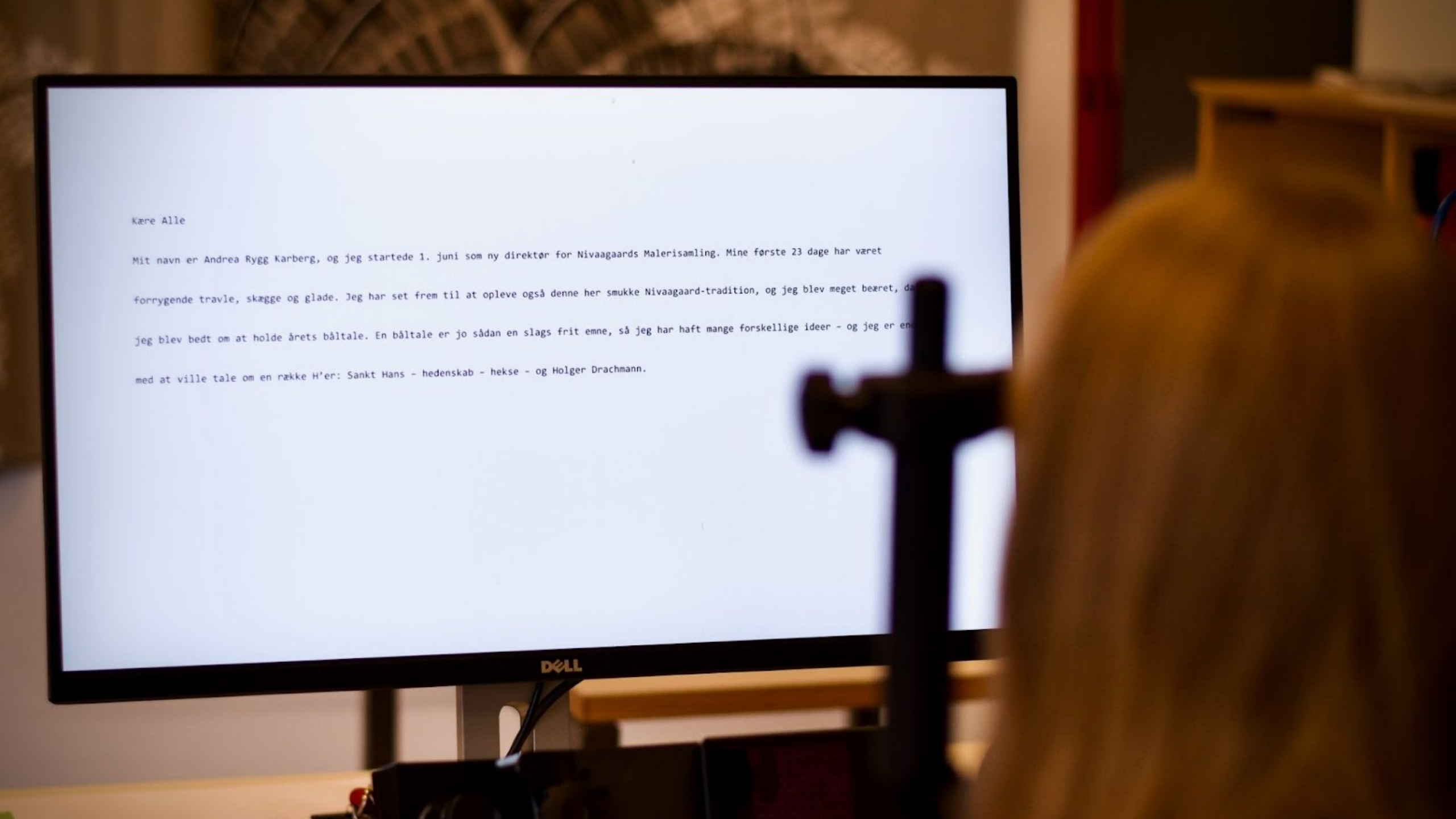
What eye-tracking can teach us about language processing

Nora Hollenstein
Center for Language Technology

UNIVERSITY OF COPENHAGEN

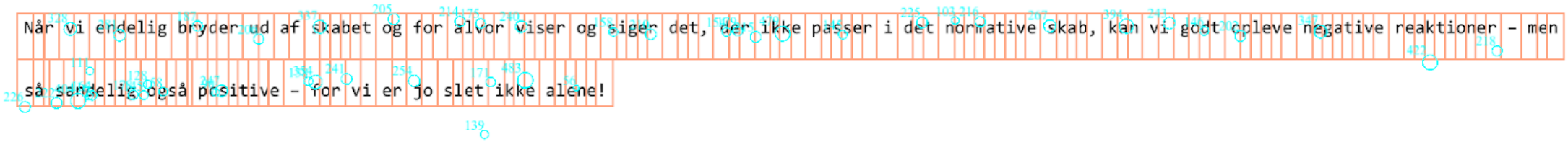
Overview

- The basics of eye-tracking
- Eye-tracking in (psycho-)linguistic research
- Eye-tracking in natural language processing


Kære Alle
Mit navn er Andrea Rygg Karberg, og jeg startede 1. juni som ny direktør for Nivaagaards Malerisamling. Mine første 23 dage har været
forrygende travle, skægge og glade. Jeg har set frem til at opleve også denne her smukke Nivaagaard-tradition, og jeg blev meget beæret, d
jeg blev bedt om at holde årets båltale. En båltale er jo sådan en slags frit emne, så jeg har haft mange forskellige ideer - og jeg er en
med at ville tale om en række H'er: Sankt Hans - hedenskab - hekse - og Holger Drachmann.
DELL

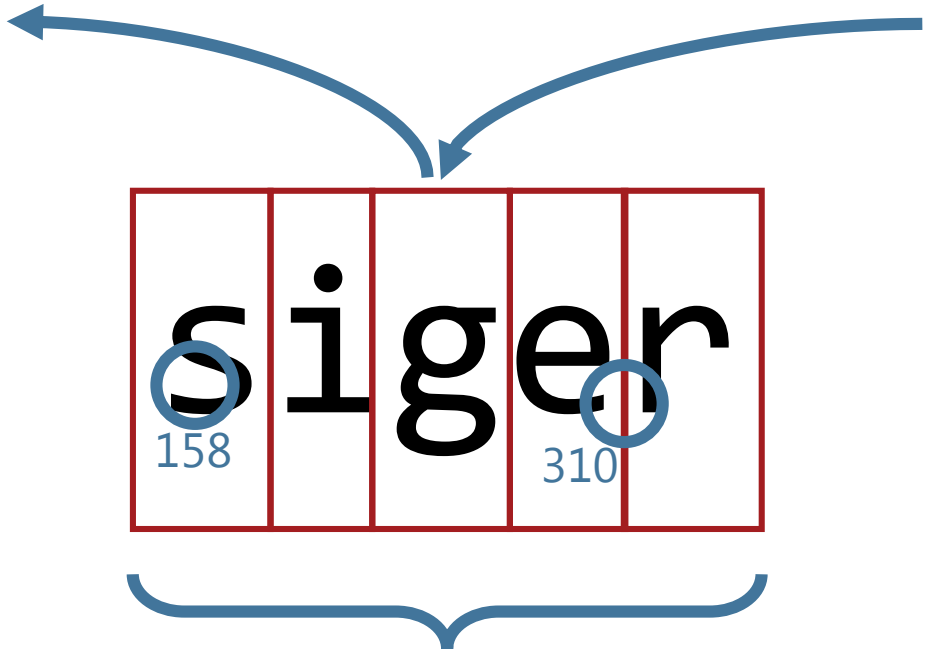

DELL

Eye-tracking features



Eye-tracking features

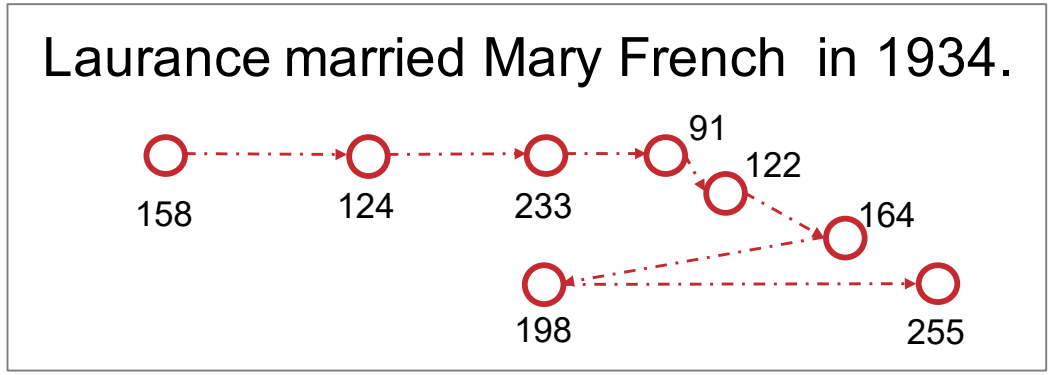
- First fixation duration
- Landing position
- Mean fixation duration
- Saccades from/to word *w*
- Total reading time
- …



→ provides information on all levels of text processing

Eye-tracking to study language processing

Psycholinguistics & reading research



- Online, real-time metrics of natural reading in an ecologically valid experiment set up
- Skipping behavior may indicate ease of processing
- Longer reading times may indicate confusion or difficulty
- Long regressions may indicate difficulty in incorporating context

→ insights into cognitive processing efforts, learning behavior and engagement

Applications

- Dyslexia & reading difficulties
  - Improve educational materials and learning processes
  - Insights by reading naturally
  - Taking into account individual differences
- Cross-linguistic differences
  - Native speakers vs. bilinguals vs. language learners
  - Language-specific reading and comprehension characteristics
- Machine learning
  - Predicting native language
  - Predicting proficiency
  - Classifying text readability

Eye-tracking for natural language processing

The potential of eye-tracking in NLP

Improving NLP models

- Fortuitous data: more robust models
- Availability
  - Relatively easy to collect
  - Existing datasets in various languages
- Readiness
  - Behavioral online metrics
  - Preprocessing required

Understanding NLP models

- When is a language model cognitively plausible?
  - Psycholinguistics: If it exhibits similar processing patterns as humans
  - NLP: If it makes similar decisions as humans
- “A window on mind and brain”
- Reflects human text processing

Improving NLP models with eye-tracking data

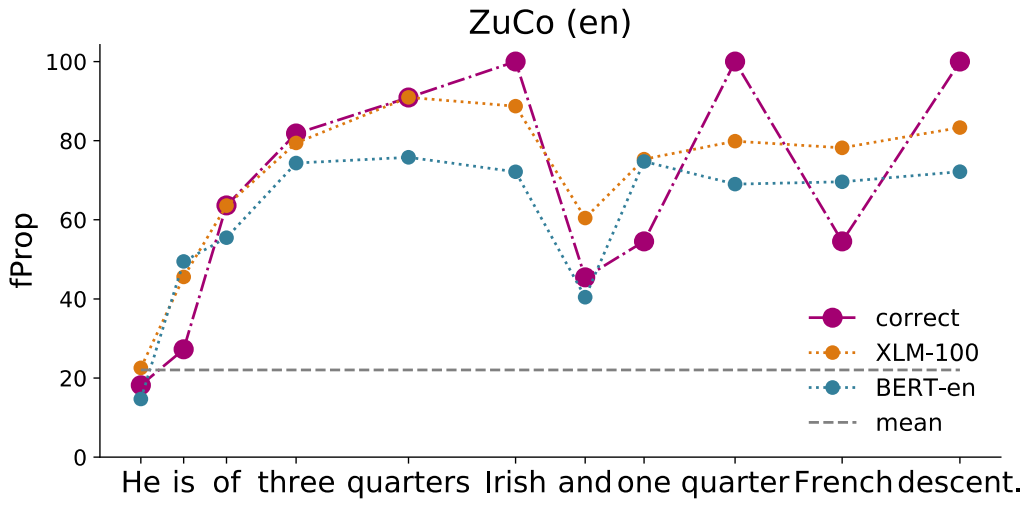
- **Multi-modal** models: learning from text and eye movements
- **Multi-task** approaches
- Modest but **consistent improvements** on various level of text processing
- **Challenge**: preprocessing decisions

NLP task	Earliest reference
Part-of-speech tagging	Barrett et al. (2016a)
Sentiment analysis	Mishra et al. (2017b)
Named entity recognition	Hollenstein & Zhang (2019)
Relation detection	Hollenstein et al. (2019a)
Sarcasm detection	Mishra et al. (2016)
Multiword expressions	Rohanian et al. (2017)
Referential/non-referential *it*	Yaneva et al. (2018)
Coreference resolution	Cheri et al. (2016)
Sentence compression	Klerke et al. (2016)
Predicting misreadings	Bingel et al. (2018)
Predicting native language	Berzak et al. (2017)
Predicting language proficiency	Kunze et al. (2013)
Dependency parsing	Strzyz et al. (2019)
Text summarization	Xu et al. (2009)

Analyzing NLP models with eye-tracking data

Predicting human reading behavior metrics

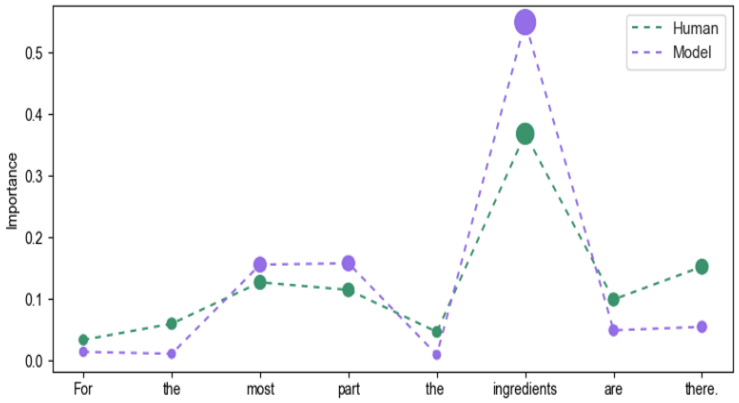
Can computational language models predict human language processing signals?



Hollenstein et al., 2021

Correlating computational and human language processing

How well do the weights learned by computational language models correlate with human patterns of language processing?



Hollenstein & Beinborn, 2021

Outlook 👀

- Eye-tracking provides online metrics of language comprehension on multiple levels of analysis
- Potential of using eye movements to build more robust NLP models
- Possibility to adjust the inductive bias of neural models towards more cognitively plausible outputs.

→ better understanding of the similarities and differences between human and machine language processing

Danish eye-tracking data

CopCo: The Copenhagen Corpus of Eye-tracking Recordings from Natural Reading

- Naturalistic reading of continuous text
- Cross-linguistic analysis of reading pattern
- Applications in psycholinguistics *and* NLP

- Participants welcome ☺
  - 1st release: native speakers
  - 2nd release: second language speakers

Thank you!

 *@norahollenstein*

nora.hollenstein@hum.ku.dk